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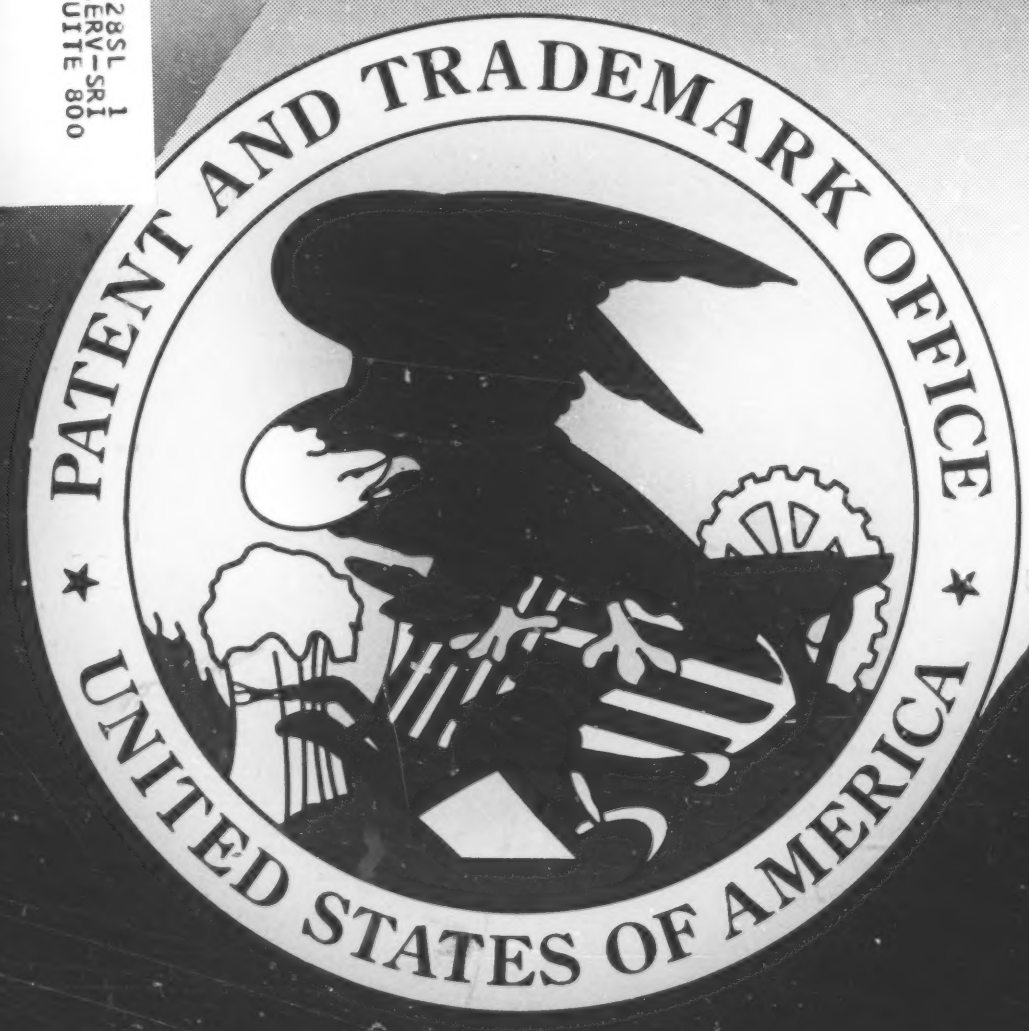

CHEMICAL & ENGINEERING
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News of the Week

■ **Chrysler Corp. is fined a record $1.6 million by OSHA for health and safety violations relating largely to lead, arsenic levels at its Newark, Del., auto assembly plant.** **Page 4**

■ **Rules to protect health care workers from occupational exposure to AIDS are urged by several workers unions.** **Page 5**

■ **Genentech loses its claim on human tissue plasminogen activator, in U.K. patent suit brought by Wellcome Foundation.** **Page 5**

■ **Mobil Chemical is presented with OSHA plant safety award.** **Page 5**

■ **Rorer Group bids to acquire A. H. Robins in a stock swap worth $2.6 billion.** **Page 6**

■ **The American Physical Society responds vigorously to severe criticism by 39 Congressmen of its recent study of the science and technology of SDI weapons.** **Page 6**

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Business

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Government

Nonregulatory federal hazardous waste reduction program could help industry realize substantial savings, environmental protection. **Page 20**

Science

Low-cost photopolarimeter that characterizes polarized light in a single measurement could increase use of light polarization analyses. **Page 22**

Education

Planned electronic supplement to education journal will promote the use of microcomputers in chemical education. **Page 23**

Challenger Center for Space Science Education is advancing plans for its education program. **Page 26**

Technology

Shortest electrical pulse yet has been made and measured by scientists at IBM, makes possible the timing of extremely brief events. **Page 26**

Science Policy

European Community fails to win approval for its ambitious research and technology development program, which is now put on hold. **Page 27**

Cover Story

The U.S. Patent & Trademark Office has begun testing an enhanced computer program as it continues in its aim to become a "paperless office." **Page 16**

Demand for Major Industrial Gases Expected To Rise Slightly

If economy continues to grow, consumption of carbon dioxide, nitrogen, and oxygen will increase 2 to 3% this year following a nearly flat 1986

Bruce F. Greek, C&EN Houston

Although demand for the various major industrial gases is forecast to grow faster than in 1986, producers are facing the same problems of low capacity utilization and low profitability they did last year. Increased activity in several industries—steel, chemical, refining, and electronics—that are large users of gases are behind the modest growth. The forecast for improved demand presumes that the current higher production in those industries will continue throughout the rest of 1987.

Production of industrial gases produced by distillation of liquefied air—including argon, oxygen, nitrogen, and the tiny volumes of rare (or noble) gases—is expected to increase about 2 to 3%, nearly double the increase of last year when the business was best characterized as flat. The outlook for other industrial gases—such as carbon dioxide, helium, and hydrogen—is expected to vary widely, because the supply/demand situations vary so much for the individual gases. Of those three, only carbon dioxide is expected to be produced in smaller quantities than last year, and that's because of limited raw material supply. Helium production and demand have continued to rise relatively fast, but consumption is about 1% that of oxygen and nitrogen combined. Most hydrogen is made and consumed on-site for making methanol, ammonia, and other chemicals, and for use in various hydro-processes, making it difficult to estimate total production accurately.

Two years of very modest demand growth for the big-volume industrial gases is bringing some longer-term changes to the industry. Many plans for capacity expansions have been put on the shelf, except for a few units whose output has been partially contracted for and their construction justified by those contracts. Other existing plants whose utilization has declined could be candidates for moving to new sites. Older units, especially the high-tonnage oxygen plants located in or near steel mills, could be scrapped before the end of the decade.

Key Chemicals

As a result of new cryogenic air separation plants that have come on stream last year and this year, capacity utilization has declined nationwide. The decline has not been large, but it has been and will continue to be sufficient to reduce profitablity in general. A turnaround in utilization, and in turn profitability, could occur in 1988 if the economy keeps growing at about its current pace. Changes in location of demand for industrial gases also will keep plant utilization uneven despite the few new plants being built (as in California and Florida, where added supply is needed by electronics manufacturers). In a few parts of the U.S. a tight supply could occur early in the 1990s, resulting from the lead time required to fabricate and erect an air separation plant, from the caution now introduced by slow demand growth, and from an upsurge in demand as new uses are developed.

Later, other methods of producing nitrogen and oxygen that have been in developmental stages for some time could account for appreciable shares of capacity. Two of the methods—pressure swing adsorption and membrane separation—are claimed to provide less expensive gases if only small quantities are needed and very high purity isn't required. If the cooling property of liquefied nitrogen also is needed, then these separation methods aren't usable. The economics involved in the choice of a system to supply nitrogen and oxygen on a smaller scale are complicated by costs of the equipment required. Demonstration of long-term economics of the use of these newer methods to produce industrial gases is needed. Hence, forecasts aren't available on how much of the industrial gases markets the noncryogenic production processes will take.

For some details of the near-term outlook for carbon dioxide, nitrogen, and oxygen, see the following pages.

Only carbon dioxide output will be down this year

	Carbon dioxide (millions of tons[a])	Nitrogen (billions of cu ft)	Oxygen (billions of cu ft)
1976	b	289	389
1977	b	329	391
1978	b	380	431
1979	b	426	455
1980	b	478	431
1981	3.45	490	431
1982	3.48	482	349
1983	3.55	560	346
1984	4.21	651	387
1985	4.24	665	393
1986	4.01	671	399
1987[c]	3.90	690	410

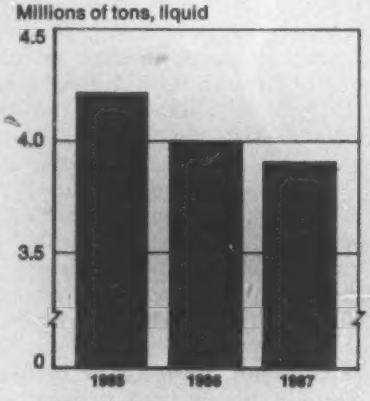
a As liquid. b Comparable data not available. c C&EN estimate. Source: Department of Commerce

CO_2

Carbon dioxide

- **Demand good**
- **Supply limited**
- **Pricing firm**

PRODUCTION



Note: Excludes CO_2 from natural sources used directly in enhanced oil recovery.

MAJOR PRODUCERS

Airco (BOC Group); Amerigas (UGI Corp.); Carbonic Industries; Cardox division of Liquid Air; Liquid Carbonic

HOW MADE

Recovered from by-product gas streams from manufacture of ammonia, hydrogen, and ethanol by fermentation; recovered from gas streams from wells drilled to produce natural gas

MAJOR MERCHANT END USES

Freezing, chilling, and transportation of food 50%, beverage carbonation 20%, chemical manufacture 10%, metals fabrication 5%, enhanced oil recovery 5%

FOREIGN TRADE

Negligible

PRICE

$70 per ton, but varies widely, depending on location, availability

Carbon dioxide output for merchant sale is expected to decline 2 to 5% this year to about 3.9 million tons as liquid because of limited supply of raw material—impure carbon dioxide—the cause of last year's decline. Production of carbon dioxide in 1986 amounted to 4.0 million tons, down about 200,000 tons from the year-earlier level. Capacity to produce the gas for merchant sale will remain on hold because of the difficulty in finding long-term, reliable sources of the raw material, despite strong demand and good prices in the marketplace.

Demand for merchant carbon dioxide continues to be strong as the two largest markets—food freezing and handling and beverage carbonation—grow. With the strong demand from uses that involve more than 70% of consumption, prices for carbon dioxide are remaining firm or increasing slightly. The firmer prices this year will have little or no effect on demand because the cost of carbon dioxide is a very small part of product cost.

Merchant carbon dioxide accounts for less than 20% of all carbon dioxide consumed. The larger part of consumption (some of which is captive) is accounted for by enhanced oil recovery, a technique to increase oil production from reservoirs. Carbon dioxide acts as a partial solvent for crude oil to reduce viscosity and helps to push oil from a reservoir.

The supply problem for merchant carbon dioxide producers stems from reduced ammonia output that, in turn, has resulted from a decline in fertilizer demand that traces back to lower agricultural prices. Although a large part of the coproduct carbon dioxide from ammonia production is consumed on-site for making urea, ammonia plants remain the largest source of feedstock for carbon dioxide producers.

Refineries making hydrogen needed for various hydro-processing operations are next in importance as carbon dioxide sources. Refineries currently are being run at levels higher than last year, but availability of carbon dioxide has not increased enough to offset losses that have occurred during the closing of other refineries. With the rapid rise in production of ethanol for automotive fuel use, fermentation plants moved into third place as sources for carbon dioxide. Because of some losses of tax incentives, fermentation of corn to make ethanol for fuel uses has become a less important source for carbon dioxide. Other potential large sources of carbon dioxide, such as stack gases, remain unexploited because technology is not yet available to concentrate the carbon dioxide economically in such streams.

Even if more raw carbon dioxide were available to producers, they still would have the same competition from liquid nitrogen and mechanical refrigeration in the food freezing, chilling, and transportation use, which now accounts for about half of consumption. The cryogenic gases—carbon dioxide and nitrogen—are still considered superior to mechanical refrigeration for freezing meats and seafoods, despite advances in mechanical refrigeration aimed at minimizing dehydration and cell damage. Nitrogen competes especially well in cost at sites where oxygen demand is strong.

Despite its large base, the entire food area is forecast to remain one of the fastest growing uses of merchant carbon dioxide because of the growing demand for fast food. Institutional markets are expected to grow faster than retail markets because of the high cost of space and limited availability for frozen foods in supermarkets.

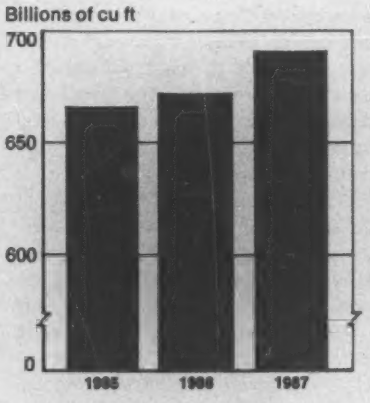
Beverage carbonation, at about 20% of carbon dioxide consumption, distantly follows food freezing and handling. This market has no competition and continues to grow at about twice gross national product, even as the baby boom slows. Soft drinks account for three fourths or more of the beverage carbonization market, with the "light" beers taking most of the remainder.

N_2

Nitrogen

- *Demand up slightly*
- *Capacity growth minor*
- *Prices steady*

PRODUCTION



Note: Reported production in gaseous and liquid forms of varying purities.

MAJOR PRODUCERS

Air Products & Chemicals, Airco (BOC Group), Big Three Industries (L'Air Liquide), Liquid Air, Union Carbide's Linde division

HOW MADE

Distillation of liquefied air; pressure swing adsorption using various adsorbents; separation using membranes

MAJOR END USES

Blanketing for chemical processing 25%, enhanced oil recovery 20%, electronics manufacturing 20%, metals treating and processing 15%, food freezing 5%

FOREIGN TRADE

Negligible

PRICE

50 cents per 100 cu ft

The merchant and pipeline segments of nitrogen demand will grow in divergent patterns in 1987. Merchant demand, almost always delivered in smaller quantities than pipeline (even though merchant sometimes is delivered by pipeline), could grow twice as fast, at 4%, as the demand for pipeline. The average overall growth will range from 2 to 3%, with production of all forms reaching about 690 billion cu ft.

In terms of volume, the nitrogen delivered by pipeline dominates the business. Most pipeline nitrogen is delivered as a gas, the preferred phase for one of the largest uses—blanketing or providing an inert atmosphere for vessels and other equipment in which chemicals are manufactured. Some of the pipeline nitrogen may be produced on-site in an air separation plant adjacent to a single consumer. Depending on current economic conditions, nitrogen delivered by pipeline accounts for 65 to 75% of reported production.

The remainder of nitrogen produced and reported as an industrial gas is delivered either as liquid or as a mixture of liquid and gas. Other large quantities of nitrogen are produced by burning hydrocarbons in air to make anhydrous ammonia.

With the possible exception of enhanced oil recovery (EOR) projects, all major end uses of nitrogen will increase in demand in 1987. The two largest are as blanketing atmospheres in the manufacture of chemicals and of electronic components. Because of the varying fortunes in recent years for both of these industries, it is unclear which of them now is the larger. Various metals production and treating, EOR, blanketing in petroleum refining, and food freezing and blanketing follow in volume of consumption.

Use of nitrogen in chemical manufacture has rebounded in the past year. Consumption of nitrogen in chemical processing, however, does not relate directly to the level of capacity utilization. Nitrogen used in chemical manufacture goes to more than blanketing of reactors and other vessels. For example, nitrogen may be used to dry reactants and products or to help regenerate catalysts and adsorbents. Prospects for growth there directly depend on expansion of chemical production capacity which, relative to the expansion of the 1970s, could be small until 1990 or later.

Nitrogen demand in electronics manufacturing is growing slower than earlier in this decade, partly because the growth is from a larger base and partly because of a slowdown in that industry. The net impact on suppliers of nitrogen, however, has been less than might be expected. As sophistication in electronic components increases, so does quality requirements of materials. Nitrogen is used both to help make materials and to preserve them as they are used. Consequently, the quality specifications for nitrogen have increased more rapidly than has demand. Consumers of nitrogen in the electronics industry have willingly paid the higher costs of better quality and improved service provided by suppliers. Strong competition is keeping prices of nitrogen level. Although the 15- to 20%-per-year growth in nitrogen going to electronics has ended, a growth rate above the average is forecast for the near term.

Use of nitrogen in making steel and in treating and fabricating various metals has grown, partially in line with the recovery in output of automobiles and various other durable goods. Despite technical developments that require more nitrogen in various small-volume treating activities, demand in metals use will grow little, probably less than 2% this year.

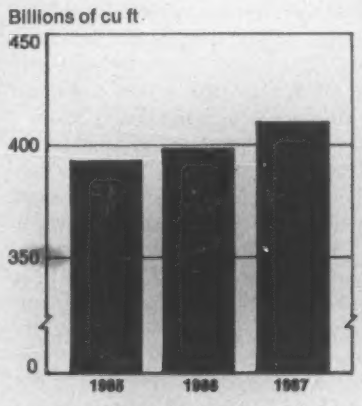
Other outlets for nitrogen are petroleum refining, food freezing, float glass manufacture, aerospace, aerosol packaging, and many small uses. Demand by most of these uses as a group is expected to increase slightly this year, about at the average rate for total demand of nitrogen as an industrial gas.

O_2

Oxygen

- *Output rise modest*
- *Capacity growth minor*
- *Pricing on hold*

PRODUCTION



Note: Reported production in gaseous and liquid forms of varying purities.

MAJOR PRODUCERS

Air Products & Chemicals, Airco (BOC Group), Big Three Industries (L'Air Liquide), Liquid Air, Union Carbide's Linde division

HOW MADE

Distillation of liquefied air; pressure swing adsorption using various adsorbents

MAJOR END USES

Primary metals manufacturing 55%, chemical manufacture 20%, partial oxidation processes 10%, metals fabrication 5%

FOREIGN TRADE

Negligible

PRICE

54 cents per 100 cu ft

Demand for oxygen will grow less this year than that for its coproduct, nitrogen. The lower growth remains tied to the consumption pattern for oxygen, which is dominated by steelmaking. As steel goes, so goes oxygen, because more than 50% of oxygen consumption is in steel production and fabrication.

Oxygen output in 1987 likely will increase more than it did in 1986, barring any long strike in the auto industry later in the fall. Growth this year will be about 10 billion cu ft, or 2.5% over 1986 output, for a total of 410 billion cu ft. The gain in 1986 was less than 7 billion cu ft because of a long strike in the steel industry. If 1987 production reaches the 410 billion cu ft expected, it, nevertheless, will be well below the peak output of 455 billion cu ft in 1979 and below the levels of the good years of 1978 to 1981.

Steelmaking, although staging a comeback in 1987 as a consumer of oxygen, will account for little of the growth in demand, probably less than 20% of the gain. Chemical manufacture (another resurging use) and various specialty uses of oxygen are forecast to account for most of the growth this year. The specialty uses, all of which are in the merchant market (in contrast to the pipeline or tonnage oxygen market), are the more profitable markets for oxygen.

The whole area of metals processing and fabrication accounts for more than 60% of oxygen consumption. Steel processes using oxygen enrichment start with conversion of iron ore in blast furnaces to pig iron, followed by purification to steel in basic oxygen or other furnaces. Oxygen demand for steelmaking has declined. Steelmaking alone once took more than 60% of oxygen; now it takes less than 50%. Even though technology is shifting toward more use of oxygen per ton of steel, future growth will be small.

Fabrication of metals is another slow-growth market for oxygen that is a part of the metals use of oxygen. This use accounts for about 5% of oxygen demand. Most of the consumption is in steel cutting and welding, but significant quantities also are used in fabricating nonferrous metals.

In another area of metals processing, oxygen is used to enrich air in smelting nonferrous metal ores, especially copper. Oxygen aids this process by reducing energy requirements and by improving sulfuric acid recovery necessary to meet air pollution control requirements. The depressed demand for copper especially has held down growth in this use of oxygen during recent years.

Chemicals manufacture, at 20 to 25% of total oxygen demand, ranks as the second largest consumption area. Well over half of the oxygen consumed (and nearly 15% of total oxygen consumption) in this use goes to make ethylene oxide. Propylene oxide manufacture is a distant second, at about 10%, of oxygen consumption for chemicals. As a group, chemicals manufacture will increase oxygen consumption more than will any other category on a volume basis.

Among specialty uses of oxygen, medical and life support applications are among the fastest growing, with the rate for 1987 expected to be about 7%. The base of these uses is small, at less than 5% of total oxygen consumption. Because the quantity used is small in any single application and the number of use locations large, much equipment is required for medical uses. Although most consumption remains cryogenically produced oxygen delivered as liquid and regasified, the lower-purity oxygen from pressure swing adsorption and membrane separation is receiving more acceptance.

Other specialty uses are developing, such as pollution control processes and aerospace. As a group, those newer uses could contribute importantly to the demand increase this year. But the growth will be largely the result of resumption of engine testing in the space program.